sustainability

Editorial

Biodiversity Conservation and Sustainable Urban Development

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Received: 8 June 2020; Accepted: 11 June 2020; Published: 18 June 2020

Abstract: Urbanization is a major driver of environmental change and is closely linked to the future of biodiversity. Cities can host a high richness of plants and animals, and this urban biodiversity supports multiple regulating, provisioning and cultural ecosystem services. Developing biodiversity-friendly cities is thus inextricably linked to sustainable urban development and human wellbeing. The contributions to this Special Issue on "Biodiversity Conservation and Sustainable Urban Development" in the journal *Sustainability* illustrate the role of urban environments as pressures on biodiversity, and envision pathways towards developing more biodiverse urban environments that are accepted and supported by people. Contributions reveal promising opportunities for conserving biodiversity within many urban landscapes. The insights from this Special Issue can support urban conservation policies and their implementation in the development of sustainable cities.

Keywords: biodiversity conservation; conservation policies; biodiversity-friendly management; nature-based solutions; socio-ecological systems; urbanization

1. Introduction

Urbanization is a major driver of environmental change and is closely linked to the future of biodiversity. Urban growth and the ongoing densification of many cities around the globe challenge the existence of ecosystems of conservation concern in and around urban regions, and the survival of species within cities [1]. At the same time, some urban environments host a high richness of plants and animals, including endangered species [2,3]. Urban biodiversity policies could thus help combat the global biodiversity crisis [4,5]. Therefore, disentangling the multidirectional—i.e., positive, negative or neutral—relationships between urbanization and biodiversity is a hot topic for urban ecological research, and new scientific insights are urgently needed to support effective urban conservation strategies.

Biodiversity-friendly cities are inextricably linked to sustainable urban development and human wellbeing. Urban nature generates and supports a broad array of regulating, provisioning and cultural ecosystem services [6], promotes physical and mental health [7], and maintains people's connection to nature [8]. Importantly, there is growing evidence of the added value of biodiverse, over simply 'green', areas in cities. Biodiversity is often (albeit not always) positively related to the delivery of ecosystem services that benefit urban residents [9,10]. Therefore the quality as well as the quantity of urban nature matters to people and contributes to their wellbeing. Enhancing biodiversity within urban settings is one important pathway to creating more livable cities.

Urban conservation strategies are increasingly part of the global urban agenda. The New Urban Agenda, the declaration from the third bi-decadal United Nations Habitat conference on human settlements, calls for universal access to green space but also the conservation of species in cities [11]. The Sustainable Development Goals call for the loss of biodiversity to be halted, and the extinction of threatened species prevented. Integrating this thinking into the built environment has been identified as a key pathway to achieving these outcomes [12]. The Intergovernmental Panel on Biodiversity and Ecosystem Services identifies "Building sustainable cities that address critical needs while conserving nature, restoring biodiversity, maintaining and enhancing ecosystem services" as a key approach for achieving sustainability [13,14].

To achieve their goals, urban biodiversity conservation strategies must consider the nature of cities as socio-ecological systems by incorporating people's values, attitudes and behaviors [15,16]. A better understanding of the people–biodiversity intersection promises to drive success in developing cities that are attractive as shared habitats for people, plants and animals.

The contributions to this Special Issue on "Biodiversity Conservation and Sustainable Urban Development" in the journal *Sustainability* aim to increase our understanding of the role of urban environments as pressures on biodiversity, and also envision pathways towards developing more biodiverse urban environments that are accepted and supported by people.

2. Geographical Range and Systems Addressed

This Special Issue covers a broad geographical range, with contributions from Africa [17], Asia [18–20], Australia [21,22], Europe [23–30] and North America [31–33]. It explores a range of ecosystems in the urban realm, spans natural remnants such as forests [30,32], wetlands [18,21], and natural grasslands [17,22], traditional urban greenspaces including cemeteries [33], gardens [29,31], and, finally, novel urban ecosystems such as green roofs and constructed wetlands [20,26], built-up areas [23], railway bridges [24] and emerging forests on vacant land [27]. In combination, a wide range of socio-cultural and environmental settings are explored and discussed.

Several papers explore biodiversity in relation to diverse features of urban environments and address a range of animal groups [21,24,27,31,33] and plants [17,18,20,22,27,30,32], including some multi-taxa studies [24,26,27]. Other papers explicitly address urban environments as socio-ecological systems [19,22,25], or further methodological approaches in understanding the people–nature intersection in cities [23,28,29]. Our selection of papers address four current topics in urban ecological research: pressures on biodiversity in cities, opportunities for biodiversity in cities, biodiversity as a component of socio-ecological systems, and new methodological approaches to urban biodiversity conservation and sustainable urban development (Figure 1).

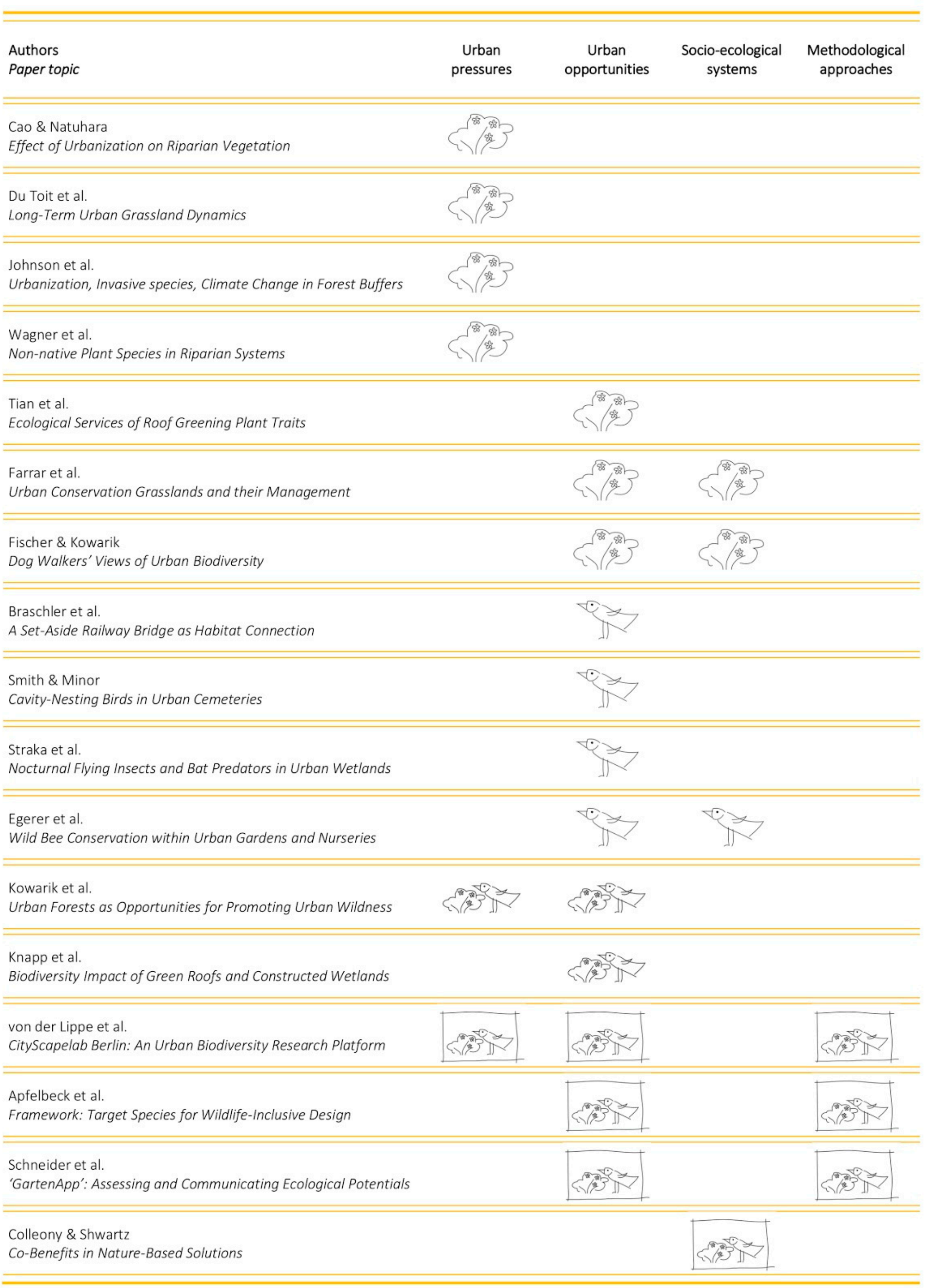

Figure 1. Contributions to the Special Issue covering four main topics: urban pressures on biodiversity, urban opportunities for biodiversity, socio-ecological systems and new methodological approaches. Icons indicate whether the paper primarily addresses plants, animals, or both; icons with a box indicate conceptual papers.

3. Urban Pressures

While many plant and animal species can colonize cities, their survival in urban environments is often challenging, as shown by local extinctions [34] and failures in population establishment [35,36]. A better understanding of the pressures that urban environments exert on nature in cities is necessary to support urban biodiversity conservation.

Three papers address pressures on riparian systems—an important issue, since many cities have grown around rivers and associated floodplain vegetation, and these often remain as natural elements within city boundaries. Johnson et al. [32] illustrate the extent to which riparian forests in a highly urbanized coastal region of the eastern United States are exposed to multiple pressures: urbanization, invasive species, and sea level rise due to climate change. Almost all forest patches were adjacent to urban development, and a considerable proportion would be inundated in different sea level rise scenarios. Almost all forests had been invaded by non-native species, most prominently by introduced shrubs and vines, while the great majority of tree saplings were native. In another study, Wagner et al. [30] found that the riparian forests of the Danube within the metropolitan region of Vienna, Austria, were highly susceptible to invasions by alien tree species. Interestingly, urbanization was positively related to the presence of some, but not all, of the most frequent alien tree species. This indicates that an influx of non-native propagules from both urban and rural sources contributes to alien tree invasions in these riparian forests. In a study of shrubs and herbs in two riparian systems in Japan, Cao and Natuhara [18] found that species richness was higher in more urbanized sites in parks, mostly due to the presence of exotic and ruderal species, but higher in more rural sites in semi-natural wastelands. In combination, these papers on biological invasions as a pressure on urban biodiversity demonstrate the need for context-dependent assessments, as different patterns are found in different regions, study systems and taxonomic groups.

A further three papers explored pressures on urban grasslands and urban forests. In emerging forests on vacant land, Kowarik et al. [27] show that non-native species also play an important role in contributing to biodiversity and conservation. Alien and native species richness in vascular plants were positively related, and endangered vascular plants and invertebrate species occurred independently of the dominance of alien or native trees. In Potchefstroom, South Africa, Du Toit et al. [17] found that native forb species were being lost from both open and woody urban grasslands, but found no evidence of biotic homogenization over the last 25 years. The suppression of fire and woody plant encroachment are common pressures on grasslands following urbanization. In Melbourne, Australia, Farrar et al. [22] found that functional traits converged in areas subject to disturbance by woody plant encroachment and fire. As expected, reintroducing fire promoted native species. However, woody encroachment contributed to habitat diversity and was associated with a different suite of dominant native species. Once again, these findings highlight that patterns and processes are context specific, and care should be taken when generalizing findings across regions, systems and taxonomic groups.

4. Urban Opportunities

The role of cities in harboring high levels of biological diversity and important components of biodiversity such as endangered species is increasingly evidenced [3,37]. However, the habitat functions of distinct urban land-use types differ conspicuously [38,39]. In depth-information about conservation opportunities associated with individual urban land-uses or ecosystem types would support policies supporting biodiversity-friendly development. A range of papers in this Special Issue demonstrate how different urban ecosystems can support biodiversity in urban settings, and expand opportunities for biodiversity-related management approaches.

Designed urban greenspaces offer many opportunities as shared habitats of people, plants and animals. One important opportunity is the introduction of biodiversity-sensitive management techniques to manage particular land uses. Smith and Minor [33] show that cemeteries in Chicago, United States, are home to a considerable number of cavity nesting birds. They reveal how landscape-level features explain patterns in the species richness of these bird species, and site-level features influence habitat selection for some species. Their conclusions on creating more biodiversity-friendly cemeteries include promoting sufficient snag availability, sympathetic mowing regimes, and planting designs such as clusters of trees and shrubs to promote particular species. Farrar et al. [22] show how novel management techniques could help overcome some pressures on native grasslands, such as using trees to create habitat complexity and refugia for some native species in grasslands where natural disturbance by fire has been suppressed.

Biodiversity sensitive planning is also an important pathway to achieving conservation with sustainable development. While habitat fragmentation is a ubiquitous challenge in urban regions, Braschler et al. [24] show in a case study of a set-aside railway bridge in Basel, Switzerland, that small-scale measures can make a useful contribution to addressing this challenge. They reveal that abandoned elements of the transportation infrastructure can help connect urban habitats for a range of animal taxa and should thus be integrated into urban biotope network schemes. Kowarik et al. [27] demonstrate the habitat functions of forests emerging on vacant urban land in Berlin, Germany, for plants and invertebrates, and argue that we should integrate these informal ecosystems into the urban green infrastructure.

The number of submissions exploring invertebrates and complex species interactions highlights the substantial progress occurring in our understanding of urban ecosystems. In Melbourne, Australia, Straka et al. [21] explored the relationship between bats, insects and wetlands. They found that increased insect diversity or abundance of some insect orders (particularly Lepidoptera) were positively associated with bat activity for all species studied. Low levels of sediment pollution in wetlands and high levels of green vegetation cover around wetlands were the most important local and landscape factors supporting insect diversity and abundance. Wild bee conservation is a worldwide issue, and many cities are developing strategies to support wild pollinators in anthropogenic habitats. Egerer et al. [31] provide advanced insights into the effects of local and landscape management in urban gardens and nurseries. Among other factors, increasing floral richness in both settings supported wild bee species richness. Schneider et al. [29] illustrate how a web application based on GIS (Geographic Information System) could support the biodiversity-sensitive management of gardens through an information exchange with gardeners.

Cities provide opportunities for new approaches to supporting biodiversity that would not be feasible in most rural landscapes. Green roofs and constructed wetlands are important decentralized eco-technologies for the adaptation of cities to climate change. Knapp et al. [26] systematically review how different measures of biodiversity relate to features of these anthropogenic systems and identify pathways towards enhancing biodiversity within these eco-technological systems. Tian et al. [20] evaluate the ecological services of more than 200 green roof plants in Beijing, China. Based on their analyses, they propose that a multitude of plant characteristics can increase the ecological functions of green roofs, and should be considered in ecologically inspired planning of green roofs.

5. Socio-Ecological Systems

Cities are coupled socio-ecological systems [15], and understanding the people–nature interface is necessary to disentangle the important drivers of urban biodiversity, and to inform successful urban conservation policies. Understanding residents' values, attitudes and behavior towards urban nature can support the development and successful implementation of urban conservation policies and ecological management [16]. Farrar et al. [22] show that, unexpectedly, prescribed burning of conservation grasslands was generally acceptable to many nearby residents and that these attitudes were based on environmental values and beliefs as well as features in the landscape. Unsurprisingly, the removal of trees was not acceptable to most residents. They conclude that grassland management permitting some woody encroachment and the use of prescribed burning may be both ecologically beneficial and socially acceptable.

Within cities, nature-based solutions are used to increase the connection of people to nature, deliver environmental ecosystem services such as cooling, and support biodiversity conservation.

However, the mechanisms underpinning these benefits, and the interactions between the different pathways are poorly understood. Colléony and Shwartz [19] introduce a social-ecological framework that integrates co-benefits to optimize social, environmental and ecological outcomes for urban planning. This framework identifies how experiments and modelling can be used to better understand mechanisms and the synergies and tradeoffs between different benefits.

Interactions with nature have been shown to support people's commitment to biodiversity conservation. Fischer and Kowarik [25] analyzed whether dog walking, a very common people–nature interaction in cities, was associated with a more positive view of urban green spaces, and the biodiversity within them, across five European cities. No difference was found in how much people preferred biodiverse urban scenes in dog walkers and non-dog walkers; therefore, the challenge of balancing the positive social outcomes and negative ecological outcomes of dog walking remains for urban planners and land managers.

6. Methodological Approaches

The last group of papers are more conceptually oriented. They address the methodological challenges of understanding patterns of urban biodiversity and related ecosystem services and how to involve different groups of stakeholders in urban conservation programs and projects.

New urban development projects offer the opportunity to integrate biodiversity at an early stage of urban development. In these projects, it is essential to clarify which species can be successfully integrated into design projects. To this end, Apfelbeck et al. [23] developed a conceptual approach for selecting target species for wildlife-friendly design, using the regional species pool as a starting point to develop a list of potential local species that could be suited to a site given dispersal and local habitat characteristics. Stakeholders can then be engaged using a participatory approach to identify focal species.

While private gardens are important green spaces in many cities, their potential to provide ecosystem services and support urban biodiversity is often underestimated due to data deficiencies. Schneider et al. [29] present a GIS-based web application, which allows gardeners to provide information on biodiversity related features and management practices. In turn, the gardeners receive an estimate of the ecosystem services, the biodiversity friendliness that their garden provides, and some appropriate management recommendations. They highlight the potential of GIS-based web applications for urban planning and conservation.

Important advances have been made in the conceptual development of urban biodiversity research over the last decades. Challenges remain, however, in understanding the interactions between different groups of animals and plants and the spatiotemporal complexity of urbanization processes. The CityScapeLab Berlin, presented by von der Lippe et al. [28], is a novel experimental research platform, based on grasslands as a model system and aiming at an enhanced understanding of the effects of urbanization on biodiversity and related ecological functions.

7. Conclusions

The intersection of biodiversity, urban environments and people is a fascinating and important field of research. It is also a promising arena for urban policies aiming at reconciling urbanization processes with biodiversity in urban regions—for the sake of both urban residents and urban nature. While we need to continue to enhance our understanding of the multiple pressures urbanization exerts on urban nature, we argue that cities also offer promising opportunities for conserving biodiversity within all land-use types, from natural remnants to novel urban ecosystems. We hope that the insights from the contributions to this Special Issue support urban conservation policies and their implementation in the real world.

Author Contributions: All authors contributed equally to the writing and revision of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: We thank all authors and reviewers for their great contributions to this Special Issue. We would also like to thank the editorial team of *Sustainability* for the continuous and highly supportive cooperation when developing this Special Issue.

Conflicts of Interest: The authors declare no conflict of interest.

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